Modeling route choice using aggregate models

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Agenda

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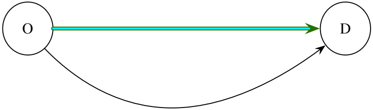
Route choice

Identify the route that a traveler would choose to go from the origin (O) to the destination (D).



- Key travel demand model.
- At the core of traffic assignment.
- Off-line and real time services and applications:
  - Decision-aid tools and transportation policies.
  - Real time operations and *route guidance*.

$\rightarrow$ **Random utility models**

- Understand, describe and predict route choice behavior.

Challenges

Operational difficulties

- Data
- Choice set
- Structural correlation

Behavioral aspect

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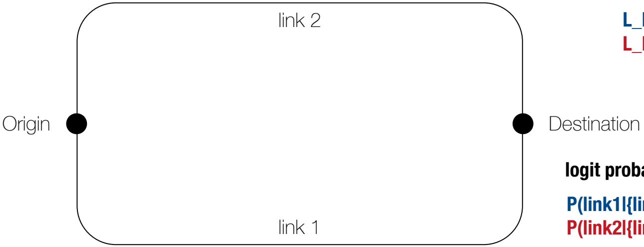
Simple example

Assumption: only the length influences the choice



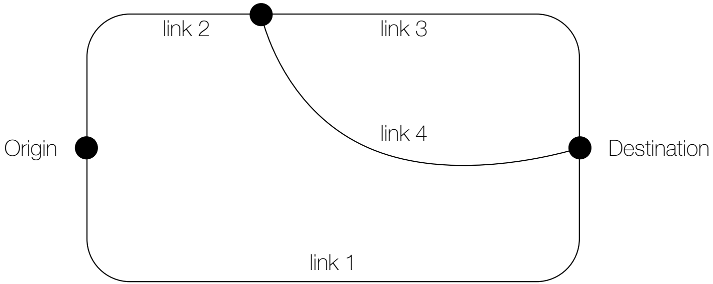
L_link1 = 10
L_link2 = 10

logit probabilities

P(link1|{link1, link2}) = 1/ 2
P(link2|{link1, link2}) = 1/ 2

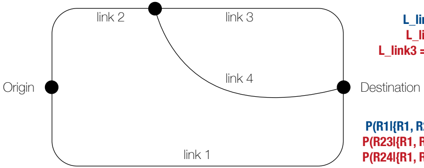
Simple example

Now let's assume that a new link is added



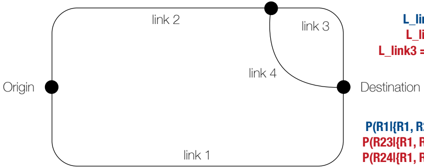
Simple example

What happens to the logit choice probabilities?



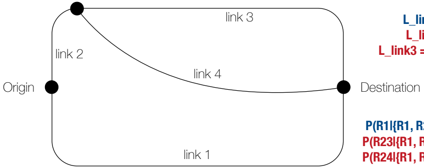
L_link1 = 10
L_link2 = 5
L_link3 = L_link 4 = 5

P(R1|{R1, R23, R24}) = 0.33
P(R23|{R1, R23, R24}) = 0.33
P(R24|{R1, R23, R24}) = 0.33



L_link1 = 10
L_link2 = 9
L_link3 = L_link 4 = 1

P(R1|{R1, R23, R24}) = 0.33
P(R23|{R1, R23, R24}) = 0.33
P(R24|{R1, R23, R24}) = 0.33



L_link1 = 10
L_link2 = 1
L_link3 = L_link 4 = 9

P(R1|{R1, R23, R24}) = 0.33
P(R23|{R1, R23, R24}) = 0.33
P(R24|{R1, R23, R24}) = 0.33

Adapted from Vovsha and Bekhor (1998)

Dealing with correlation

1. In the determinist part of the utility.

   ⊙ Simple but less realistic.

   ⊙ C-logit (Cascetta et al., 1996); Path size logit (Ben-Akiva and Bierlaire, 1999).

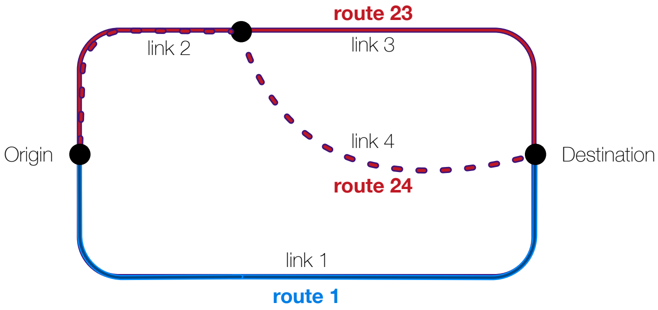
2. In the stochastic part of the utility.

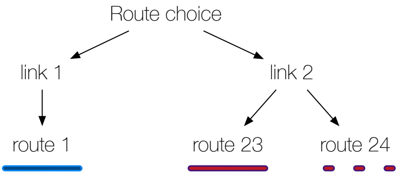
   • More realistic but complex.

   • Link nested/ cross nested logit (Vovsha and Bekhor, 1998; Lai and Bierlaire, 2015); Logit kernel (Bekhor et al., 2002; Frejinger and Bierlaire, 2007).

Capturing correlation

The nested logit model



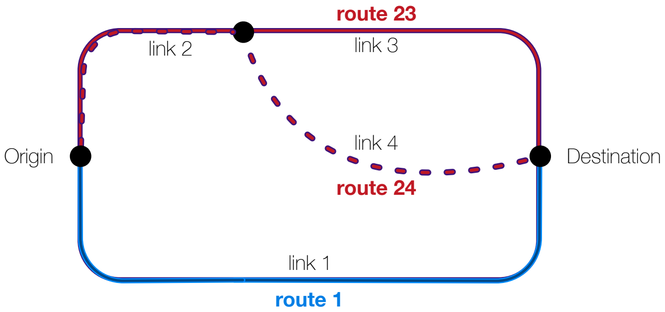


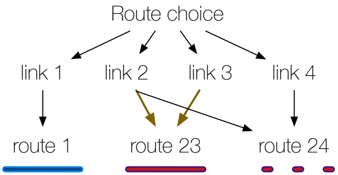
logit

expected maximum utility of route 23 and 24

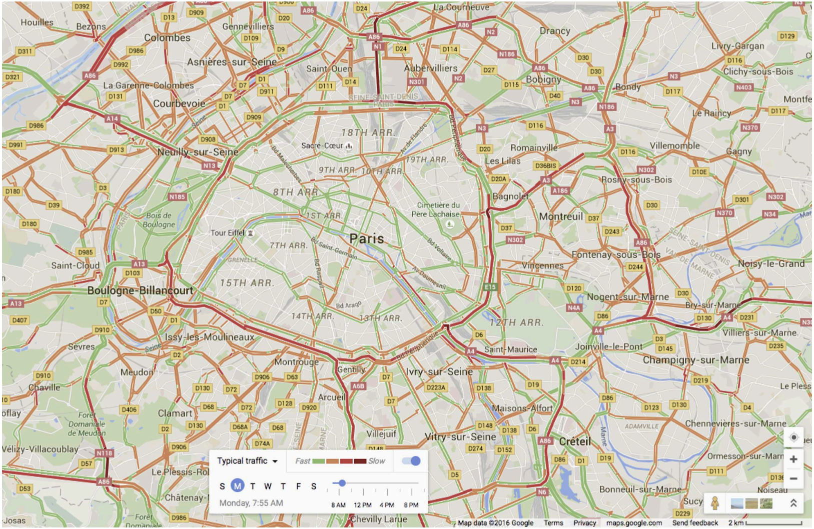
Capturing correlation

The cross nested logit model





But what happens when...



Capturing correlation

`From logit to CNL` *the # of parameters to be estimated explodes*

$$P(i|\mathcal{C}_n) = \frac{e^{\mu V_{in}}}{\sum_{j \in \mathcal{C}_n} e^{\mu V_{jn}}}$$

$$P(i|\mathcal{C}) = \frac{e^{\mu_m V_i}}{\sum_{j \in \mathcal{C}_m} e^{\mu_m V_j}} \frac{\left(\sum_{\ell \in \mathcal{C}_m} e^{\mu_m V_\ell}\right)^{\frac{\mu}{\mu_m}}}{\sum_{p=1}^{M} \left(\sum_{\ell \in \mathcal{C}_p} e^{\mu_p V_\ell}\right)^{\frac{\mu}{\mu_p}}}$$

$$P_n(i) = \sum_{m=1}^{M} \frac{\left(\sum_{j \in \mathcal{C}_n} \alpha_{jm}^{\mu_m/\mu} e^{\mu_m V_{jn}}\right)^{\frac{\mu}{\mu_m}}}{\sum_{p=1}^{M} \left(\sum_{j \in \mathcal{C}_n} \alpha_{jp}^{\mu_p/\mu} e^{\mu_p V_{jn}}\right)^{\frac{\mu}{\mu_p}}} \frac{\alpha_{im}^{\mu_m/\mu} e^{\mu_m V_{in}}}{\sum_{j \in \mathcal{C}_n} \alpha_{jm}^{\mu_m/\mu} e^{\mu_m V_{jn}}}$$

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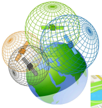
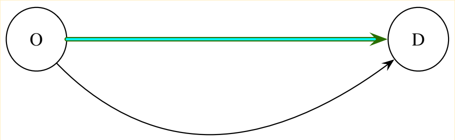
Considerations

1. Availability of data
2. Needs of the application

→ Route choice at the aggregate level



Aggregate model



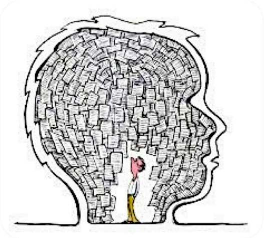
Disaggregate model

Towards aggregate route choice

How can we represent a route in a behaviorally realistic way without increasing the model complexity?

> $\rightarrow$ Model the strategic decisions of people instead of the *operational* ones.

> $\star$ **Mental Representation Item (`MRI`)**



Objective

Specify and apply an *aggregate* model to a large network with limited data.

1. Description of alternatives based on prominent elements of the network.
2. Less dependent on detailed data.
3. Lower structural model complexity and computational cost.

→ Mental representation item (MRI) model.

→ *Challenge:* the definition of the simplified structure.

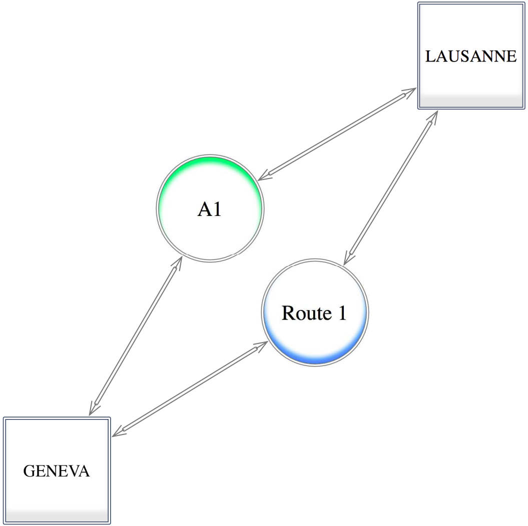
1. Kazagli, E., Bierlaire, M., and de Lapparent, M. (2017). Operational route choice methodologies for practical applications. Technical report TRANSP-OR, ENAC, EPFL.

2. Kazagli, E., Bierlaire, M., and Flötteröd, G. (2016). Revisiting the Route Choice Problem: A Modeling Framework Based on Mental Representations, Journal of Choice Modelling 19:1-23.

Goals

1. Generalization of the `MRI` choice model.
    - Conceptual model that is meaningful, operational and useful.
    - Definition of an *abstract graph* that is compatible with the standard specification and estimation procedures.
        - Link additive attributes.
        - Choice set generation; sampling of paths; link-based formulation.
    - Identification of attributes.
2. Application to Québec city.

A trivial example of a MRI model



First step: Outline of the `MRI` model

Build the image: case dependent

1. Identification of prominent elements of the area of study.
    - *Paths*: major arterials, bridges.
    - *Districts*: the city center(s), areas generating and attracting trips.
2. Identification of their interactions and interdependencies.
3. Decision on the level of aggregation.
    - How long the description *needs* to be?

      Scale and needs of the application.
    - How long the description *can* be?

      Availability and resolution of data.

Second step: Definition of the MRI graph

Structure of the model

$$G^{\mathcal{M}} = (\mathcal{L}, \mathcal{M}) \sim G = (A, \mathcal{V})$$

1. For each MRI add a node m in the MRI graph.
2. For each O and D zone add a node in the MRI graph.
3. For each pair of nodes in the MRI graph create a link ℓ if a transfer between the nodes is allowed.

$\downarrow \uparrow$

4. Associate observations with elements of $G^{\mathcal{M}}$.

Third step: Specification and estimation

Operational aspects of the model

1. Path-based formulation

   Kazagli, E., Bierlaire, M., and Flötteröd, G. (2016). Revisiting the Route Choice Problem: A Modeling Framework Based on Mental Representations, Journal of Choice Modelling 19:1-23.

2. Link-based formulation: the **Recursive Logit (RL)** (Fosgerau et al., 2013)
   1. Sequential link choice in a dynamic framework.
   2. Consistently and efficiently estimated on the full choice set of paths without sampling of alternatives.
   3. Equivalent to a multinomial logit.

Overview of the RL model

- At each state k the traveler chooses the next state a that maximizes the sum of the instantaneous utility $u_n(a \mid k)$ and the expected downstream utility $V^d(a)^*$ to the destination d.
- $u_n(a \mid k) = v_n(k \mid a) + \mu\varepsilon_n(a)$.
- $\mathbb{P}_n^d(a \mid k) = \frac{e^{\frac{1}{\mu}(v_n(a \mid k)+V^d(a))}}{\sum_{a' \in A(k)} e^{\frac{1}{\mu}(v_n(a' \mid k)+V^d(a'))}}$.
- Output: *destination specific* link transition probabilities.

- A path p is realized as a sequence of link choices, with probability $\mathbb{P}_n^d(p \mid \mathcal{U}) = \prod_{k=o}^{d-1} \mathbb{P}_n^d(a \mid k)$.

$^*V^d(a)$ are value functions computed using the Bellman equation.

Fourth step: Addressing correlation

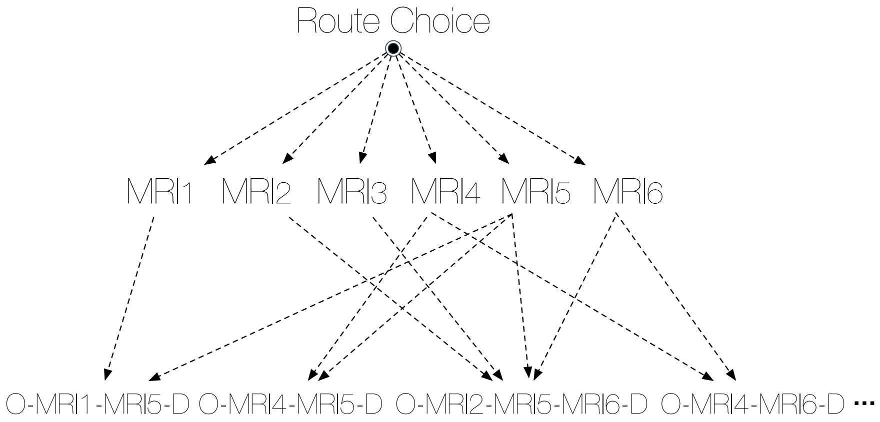
CNL with MRIs

- Each MRI corresponds to a nest.
- An alternative r belongs to nest m if MRI m appears in the sequence r.

Real network example:

- The physical network is composed of $\sim$ 7000 links that would correspond to $\sim$ 7000 nests.
- With the MRI approach we could reduce to 6 nests.

The underlying MRI nesting structure



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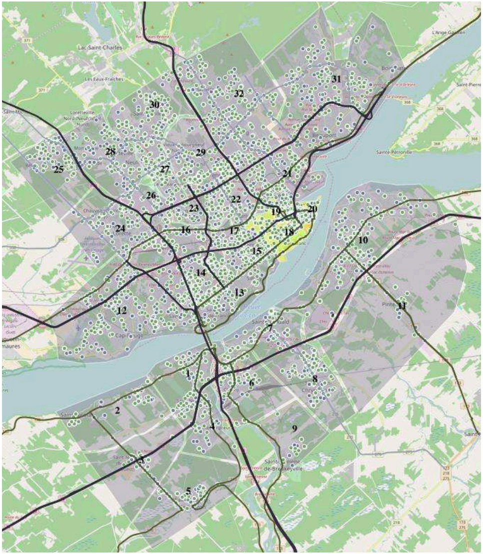
Dataset

- Québec city.
- Montrajet smartphone application (McGill university)[1]
- Data collection: April 25 to May 16, 2014.
- GPS trajectories of more around 4000 individuals.
- More than 20000 trips.

- Trip purpose.
- Departure time.

[1] Mirando-Moreno L.F., Chung C., Amyot D., Chappon H. (2014), A system for collecting and mapping traffic congestion in a network using GPS smartphones from regular drivers.

Québec city


Lac-Saint-Charles
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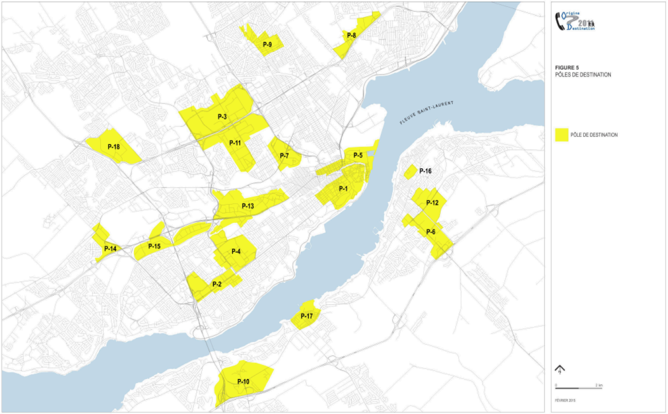
Origin-Destination survey of 2011

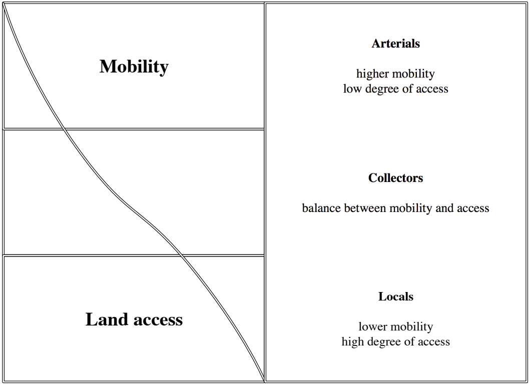
Main destination poles

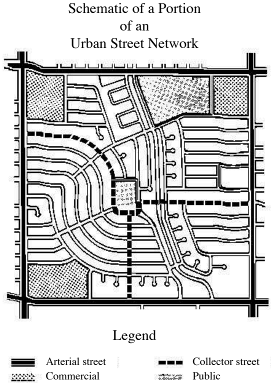
La mobilité des personnes dans la région de Québec (Mars 2015)



Most visited segments

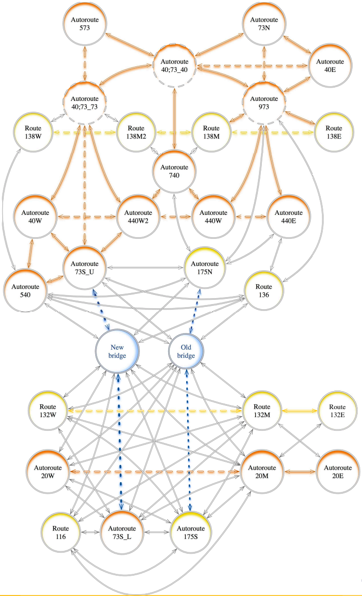
Mobility vs accessibility





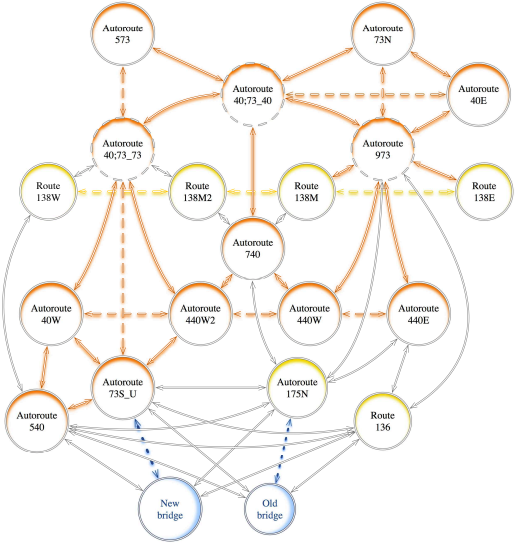
Source: Grant Benjamin, *"Grand Reductions: 10 Diagrams That Changed City Planning"*, The Urbanist, Issue 518, November 2012, SPUR Ideas + Action for a Better City

The $G^{\mathcal{M}}$ of Québec city as a dual graph



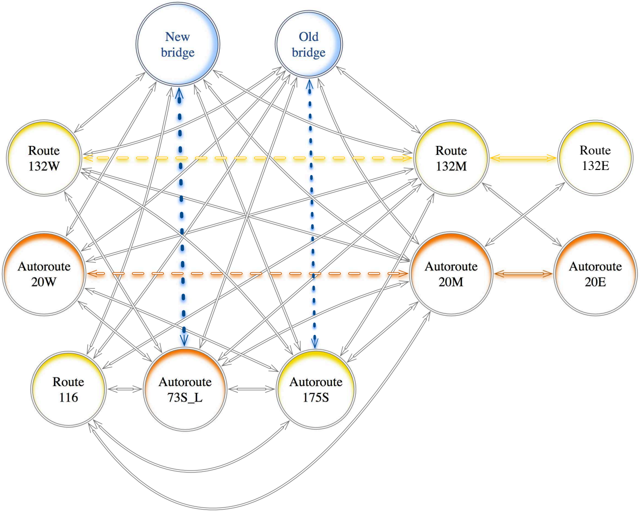
Québec city: upper side

Dual graph

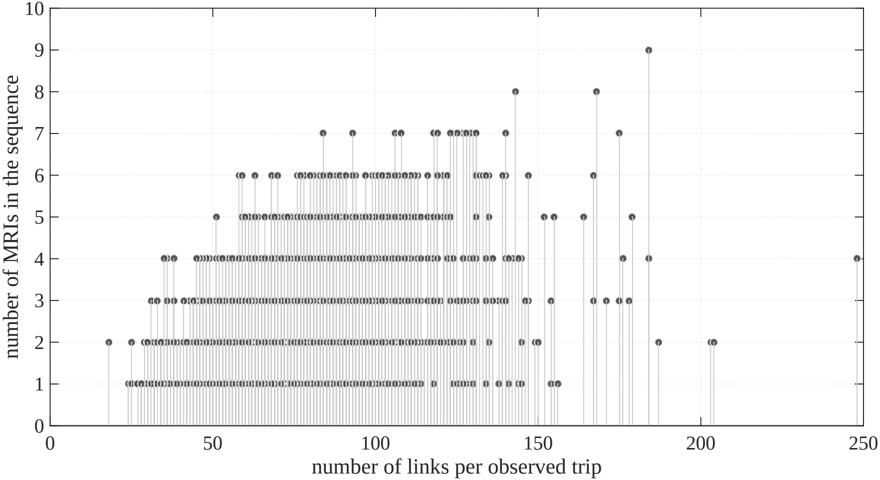


Québec city: lower side

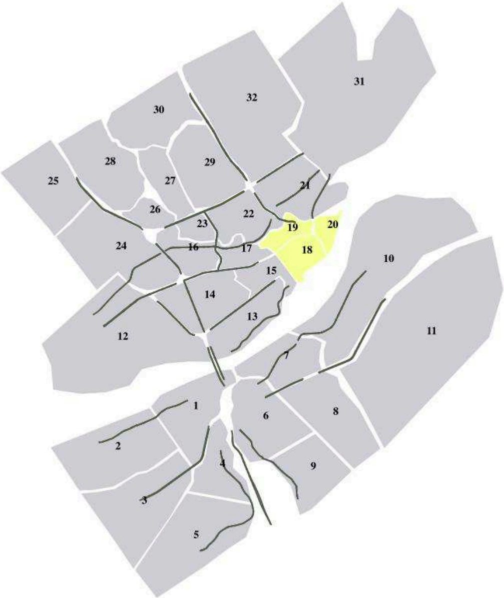
Dual graph



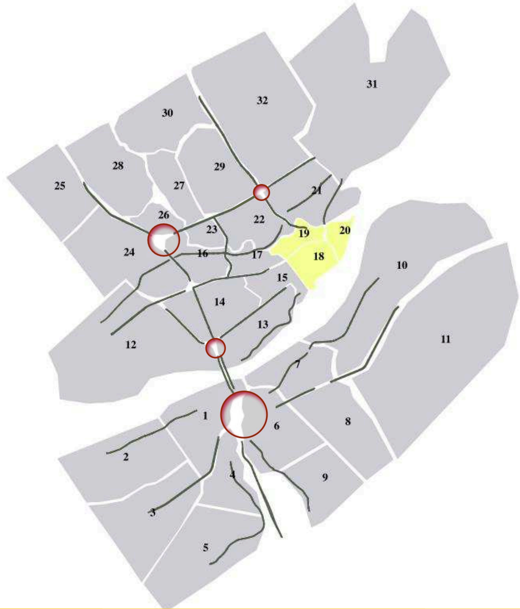
Observed number of links in G vs number of links in $G^{\mathcal{M}}$



Geographical span



Major intersections



Specification of utilities

The instantaneous utility $v(a \mid k)$ of a link pair is:

$$\begin{aligned} v(a \mid k) = \beta_{TravelTime} TT(a) + \\ + \beta_{Upgrade} UP(a \mid k) + \beta_{Downgrade} DOWN(a \mid k) + \\ + \beta_{Penalty} Transfer(a) \end{aligned}$$

where *Upgrade* $= 1$ if transfer from primary to highway, *Downgrade* $= 1$ if transfer from highway to primary, *Penalty* $= 1$ for all transfers, except those belonging to the same `MRI` (natural extension), to penalize routes with many transfers.

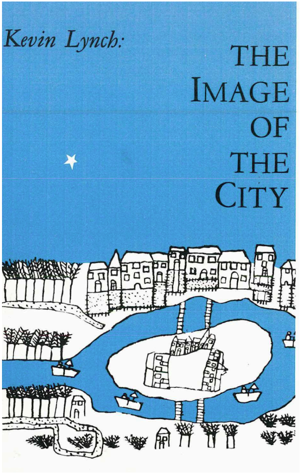
Agenda

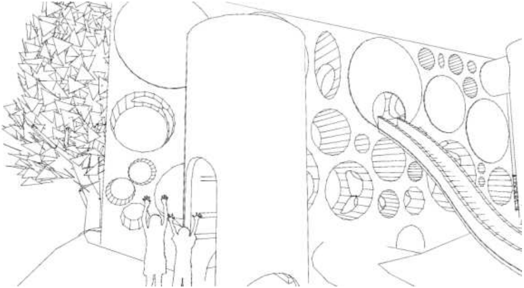
Conclusion

1. Simpler model structure.
2. Compatible with route guidance.
3. Specification and imputation of attributes is still an issue.
4. Motivates and can benefit from new data collection approaches.

Legibility

"In the process of way-finding, the strategic link is the environmental image, the generalized mental picture of the exterior physical world that is held by the individual. This image is the product both of immediate sensation and of the memory of past experience, and it is used to interpret information and to guide action. The need to recognize and pattern our surroundings is so crucial, and has such long roots in the past, that this image has wide practical and emotional importance to the individual."





Thank you!

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